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Experiences with Blight-Resistant Chestnuts *in New Jersey*

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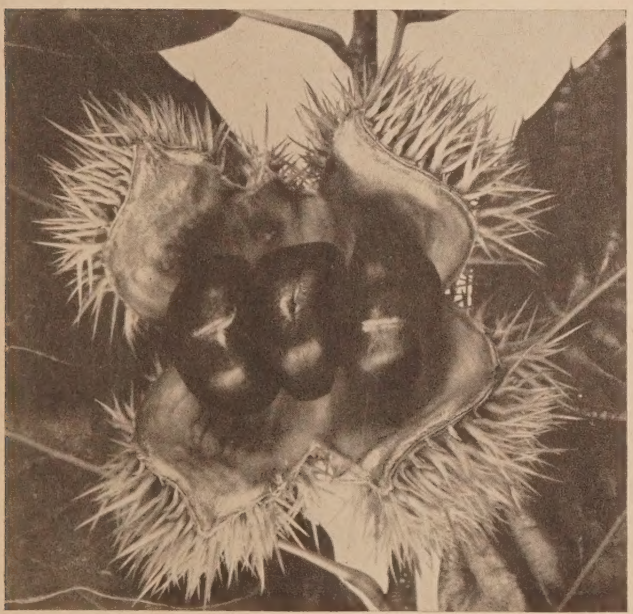

Bur with nuts of the Chinese chestnut

NEW JERSEY AGRICULTURAL EXPERIMENT STATION
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CONTENTS

PAGE

Early Tests in the United States with Foreign Species 3

Growth and Fruiting Characteristics of Chestnuts 4

Tree and Leaf Characteristics 4

Flowering Habit 6

General Characteristics of the Nuts 7

Chestnuts at the College Farm 8

Miscellaneous Specimens 8

Chinese and Japanese Seedlings 11

Varietal Selection and Development 17

Propagation 17

The Growing of Rootstocks 17

Grafting the Chestnut 18

Suggestions for Planting 19

Pest Control 20

Present Work with Chestnuts 20

References 20

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Experiences with Blight-Resistant Chestnuts in New Jersey

M. A. Blake, *Chief, Division of Horticulture,* and L. J. Edgerton

Half a century ago, the American chestnut, *Castanea dentata,* was common in the woodlands of its native habitat, the eastern United States. It was used freely for lumber, telephone poles, fence rails, and posts, and nuts were produced in considerable quantity wherever the trees had adequate light and space. In New Jersey, the chestnut thrived particularly on the more moist and heavier but well-drained soils. On the lighter, sandy soils where stands of trees such as white, post, jack, and scrub oak were abundant, the chestnut was much less common, and the trees were stunted in growth.

In 1904, the chestnut blight, an Oriental fungus disease affecting the bark, had become established in New York. The American chestnut is very susceptible to this blight, and it soon became apparent that a serious problem was at hand involving the future welfare of the great American chestnut forests. By 1908 the blight had spread to parts of northern New Jersey, and by 1912 it had extended to virtually every part of the State. In its forward sweep, this devastating disease nearly annihilated the American chestnut in the eastern forests.

Early Tests in the United States with Foreign Species

Other species of chestnuts which exhibit varying degrees of resistance to blight have been introduced into this country from time to time. For a number of years prior to the occurrence of the blight, species native to other parts of the world were being introduced and tested to a limited extent, first by private individuals and later by the U. S. Department of Agriculture (2).

The European or Spanish chestnut, *Castanea sativa,* was the first foreign species introduced. It was grown from seed and also was grafted on trees of the American chestnut. When the blight began to attack the native chestnuts, however, the European species proved to be almost as susceptible to the disease. Another species, the Japanese chestnut, *Castanea crenata,* was introduced about 1876. A limited amount of hybridizing work was done with these two species and with the American species by such men as George W. Endicott and Dr. Walter Van Fleet. The Chinese chestnut, *Castanea mollissima,* was also introduced into this country and was being distributed and tested to some extent by the U. S. Department of Agriculture about the time the blight was discovered.

When it became evident that the blight seriously threatened to eliminate our native chestnut, the species which had been introduced were observed

and tested as to their resistance to the blight. The most promising has been the Chinese chestnut. It has proved to be more blight resistant than either the Japanese or the European, and the nuts tend to combine the large size of the European with the high quality of our native species.

The Henry Chinkapin (*Castanea henryi*), another species native to China, has also been introduced into this country and is reported to be resistant to the blight (2). It may prove useful as a timber tree here and is under observation and test at various places.

Chestnut improvement in this country is being carried out largely by selection and hybridization. This work is being done both by private individuals and by State and Federal institutions.[1]

Growth and Fruiting Characteristics of Chestnuts

Nine species of Castanea are native to the temperate region of the Northern Hemisphere. Of these, the four species around which timber and nut production has largely been centered are the American, the European, the Chinese, and the Japanese. What are the distinguishing characteristics of these species, and how do the foreign types compare with the native American?

Tree and Leaf Characteristics

The American chestnut, as it grew in the woodlands of this section before the blight arrived, often reached a height of 100 feet. Its coarse-grained, durable wood made it a valuable timber tree. In contrast to the native chestnut, the Chinese and Japanese species have not attained great size here. The Japanese species is usually described as a shrub or relatively small tree growing to 30 feet in height, although specimens of larger size occur. The European chestnut, in its native habitat, is a large tree growing to 100 feet in height and having a trunk circumference of 20 or 30 feet. In this section, however, it seldom grows much larger than a good-sized apple tree and could not compare with the American species as a source of timber.

The leaf of the American chestnut is thin and papery in texture, green on both sides even when young, and has a dull finish. The blade is lance-shaped, with the angle of the apex varying from about 45 to 55° as measured by a foliarmetric gauge (4). The angle of the base of the blade varies from 70 to 90°. The blade is serrate with coarse, pointed teeth, as illustrated in figure 1.

The leaf of the Chinese chestnut is thick and leathery and has a bright green, glossy surface. The angles of both the apex and the base of the blade are wider than those of the American species (fig. 1). The measurement of

[1] A more detailed discussion of this work may be found in the 1937 Yearbook of Agriculture (1).

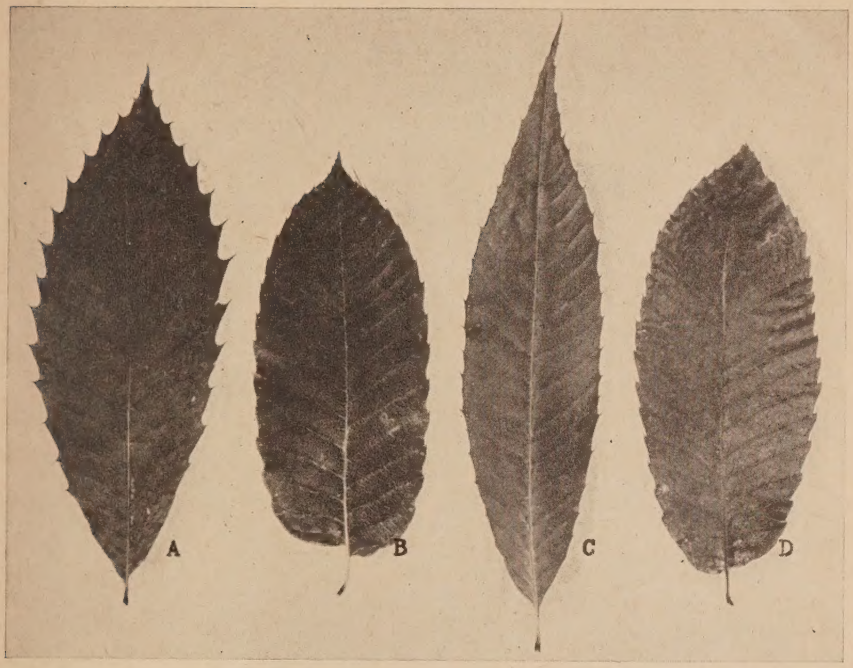

Fig. 1. Typical leaves of four chestnut species: A, American (*C. dentata*); B, Chinese (*C. mollissima*); C, Japanese (*C. crenata*); D, European (*C. sativa*).

a number of representative leaves gave apex angles varying between 70 and 90°, while the base angles varied from 110 to 130°. The base of the blade of the Chinese chestnut is somewhat rounded and sometimes terminates abruptly in a nearly straight edge. The under surface of the blade varies from whitish to nearly green and is more or less covered with short, dense, wool-like hairs, particularly when young.

The leaf of the Japanese chestnut usually is smaller than those of the other chestnuts. It has a pale green, glossy surface and is finely serrated with shallow, sharp-pointed indentations, as shown in figure 1. The apex angle of the blade is sharper than that characteristic of the other species, varying from about 30 to 40°, and the base angle is about 70 to 90°. The under surface of the blade is covered with short hairs, particularly when the leaf is young.

The leaf of the European chestnut has a bright glossy surface but is not so thick and leathery as the Chinese. The apex angle of the blade is about the same as that of the American chestnut, varying from 40 to 60°, but the base angle is wider (90 to 110°). When mature, the leaf is usually green on the under surface, and few if any hairs are present. Rehder (6) describes the leaves as being coarsely serrate. Such a leaf is illustrated in figure 1.

Table 1

Dimensions of Representative Leaves of Four Species of Chestnuts

(Average of 10 leaves for each species)

Species	Length	Width	Apex * Angle	Base * Angle
	inches	*inches*	*degrees*	*degrees*
American *(C. dentata)*	7.02	2.49	48.6	81.4
Chinese *(C. mollissima)*	5.70	2.50	74.8	118.5
Japanese *(C. crenata)*	6.77	1.84	34.3	83.1
European *(C. sativa)*	5.66	2.00	52.9	103.4

* The angles of the apex and base of the leaf blade were determined by a foliarmetric guage (4) which measures the apex angle 1 inch from the tip and the base angle ½ inch from the base.

On the tree at New Brunswick from which this specimen was obtained, such leaves are found mainly in the shaded areas toward the interior of the tree. The more exposed leaves tend to be somewhat narrower in proportion to their length, and the teeth are often reduced to short spines.

The detailed measurements of representative leaves of these four species are given in table 1.

Flowering Habit

In flowering habit, the chestnuts closely resemble the oaks, to which they are akin. The male and female flower parts of the chestnut occur on the same tree but they are borne in separate structures. Figure 2 shows a branch of the Chinese chestnut in flower. The staminate or male flowers occur on slender flexible catkins which arise from the axils of the leaves. These catkins with the thin, hair-like filaments protruding therefrom and the slightly enlarged anther at the tip of each filament can be readily seen in the illustration. The pistillate or female flowers are borne toward the base of the upper staminate catkins. The flowers are clustered, usually three together, in a prickly involucre which becomes the bur. One such cluster of pistillate flowers, enclosed in a small bur, can be seen near the base of the upper catkin in figure 2. Few pistillate flowers ever form on short, thin annual growths or at the base of short, weak catkins. There appears to be a definite relation, therefore, between the vigor of the annual growth and the development of pistillate flowers. After pollination and fertilization, the nuts develop, the

Fig. 2. Flowering habit of the Chinese chestnut. The staminate or male flowers on the first four catkins are in full bloom. A pistillate or female flower can be seen near the base of the upper catkin, the flowers of which have not yet opened.

bur increases in size, and finally at maturity, splits open exposing the ripe nuts (see cover illustration).

General Characteristics of the Nuts

The nuts of the American chestnut are small, brown, and coated around the apex with thick, pale down. The kernels are very sweet and palatable, among the most delicious known. The European species produces a much larger nut but rarely equal in quality to the American chestnut. Typical nuts of the European species are shown in figure 3. Nuts of the Japanese species are larger than those of the American, but as a rule the flavor is mild or starchy

and the texture coarse. The skin covering the kernel is often thick and difficult to remove. The nuts of the best Chinese species are almost as sweet as the American chestnut and commonly about as large, under favorable conditions, as the European. Measurements of some of the nuts produced by the Chinese chestnut trees at the College Farm in 1943 are given in table 2, showing the range in size which may occur among the nuts from seedling trees of this species. These different sizes are illustrated in figure 4. The season of 1943 was favorable for the chestnut, and the nuts averaged somewhat

Table 2

Variations in Size of Nuts Produced by Seedling Chinese Chestnut Trees at New Brunswick in 1943

	Small	Medium	Large
Number of nuts per pound	144	66	44
Number of nuts per quart	250	130	82
Average diameter—*inches*	0.82	1.08	1.27

larger than usual. The nut is mahogany-brown and commonly has an attractive surface. The skin covering the kernel usually is thin and can be easily removed when the nut is ripe.

Chestnuts at the College Farm

Miscellaneous Specimens

The American chestnut formerly made an excellent growth in the woodlands at the College Farm. In 1916 there were several very large chestnut trees in one of the hedgerows near the Weather Tower on what is now Horticultural Farm No. 1. A small Japanese chestnut grew in the collection of shade trees about the old farmhouse on its original site near the College Farm pond. This tree lived for a number of years after all the American chestnuts in the nearby woodlands had blighted, but later it became diseased and was removed.

A European chestnut tree is still growing on the former George Redshaw property near the Burnet Street circle and Highway 25. It now has a spread of about 60 feet and a trunk circumference of 6.6 feet at a height of 2 feet above the ground. According to a former resident of the Redshaw home, this tree is about 36 to 40 years old. Its top has been damaged at times by storms, but like a number of other large mature European chestnuts about the State that have resisted the blight and have grown fairly well, it has never

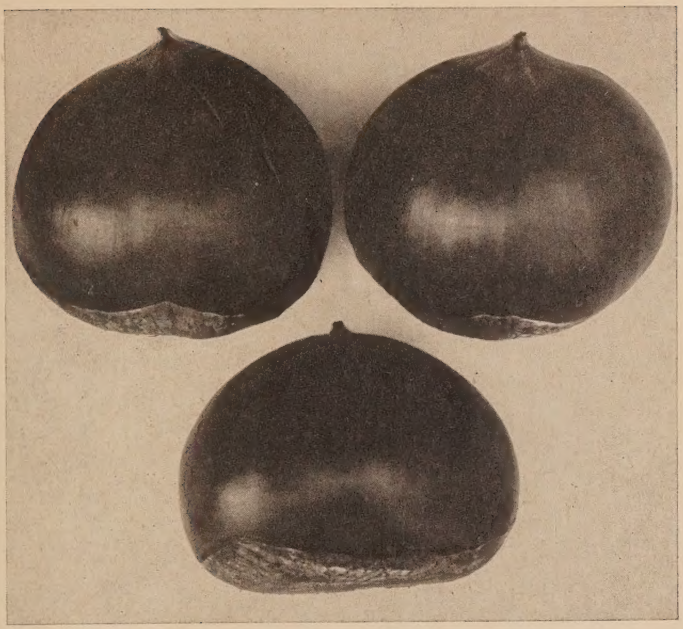

Fig. 3. Nuts of the European chestnut produced by a tree growing at New Brunswick. These nuts are nearly 2 inches from the base to apex.

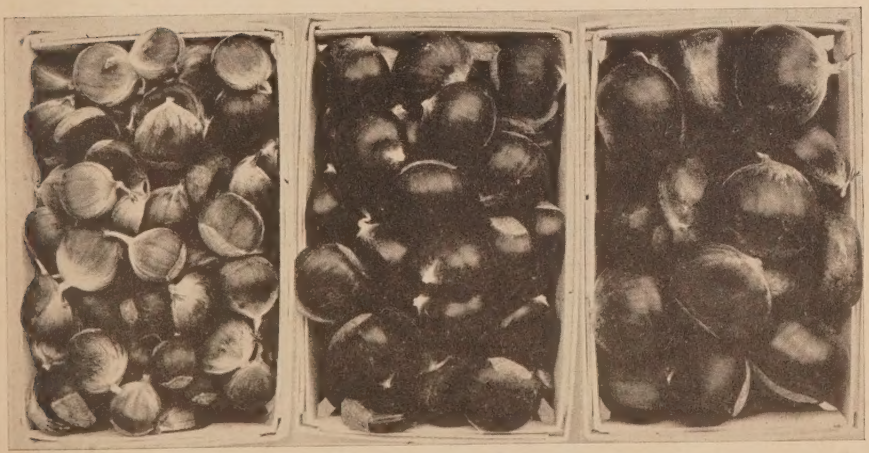

Fig. 4. Nuts of the Chinese chestnut showing range in size which occurred at New Brunswick among the nuts produced by different seedling trees.

Fig. 5. Boone chestnut in bloom, showing the long, staminate catkins.

blighted seriously. In some seasons it forms many burs but relatively few nuts, possibly because it is largely self-sterile, as is the case with most chestnuts (1).

A small collection of European varieties was planted at New Brunswick about 10 years ago, but these have since blighted. A tree of the variety Boone,[2] also planted at that time, has proved to be blight-resistant. The variety is unique among the chestnuts at the College Farm, in that it produces staminate flowers fairly regularly in the fall in addition to the staminate and pistillate flowers produced during the usual blooming period in the spring. In bloom, it is an attractive ornament with catkins 10 to 12 inches long. In figure 5, the staminate catkins can be readily seen. Normally, the nuts produced by this tree at the College Farm are somewhat larger than the medium-sized Chinese chestnuts shown in figure 4. In the dry summer of 1944, however, they were somewhat smaller, the average diameter of ten representative nuts from the crop being 1.08 inches. A quart contained about 110 nuts, with 69 nuts to the pound. The chief value of this variety, however, is as an ornamental.

[2] The Boone chestnut was developed by George W. Endicott, of Villa Ridge, Illinois, as a result of a cross made in 1895 (7) between the American chestnut and the variety known as Giant (Japan Giant).

Chinese and Japanese Seedlings

In the spring of 1926, about 150 chestnut trees of the species *C. mollissima* were set out in the test orchard. In 1931, about 25 trees were planted. Some were of the species *C. mollissima* from Peiping, China, and near Kobe, Japan, and others, of the species *C. crenata*, from the latter source. In 1936, 15 lots of two trees each of *C. mollissima* from various places in China and Japan were set out.[3] During more recent years a considerable number of seedlings from selected Chinese chestnut trees also have been grown.

Trees need well-limed fertile soil. The area on which the original test trees were planted in 1926 comprises a soil phase of loam to clay loam underlain by mixtures of Penn shale and clay. It was in a fair state of fertility when the planting was made. Since it was suggested at that time that chestnuts would grow best on acid soils, the plot was not limed at first. On one end of the field, more shallow, dry, and acid than the other, the trees did not grow particularly well, and blight developed on the trunks near the soil on a higher percentage of trees. The soil was limed, therefore, to a pH of about 6, and alternate row spaces were planted to a cover crop of sweet clover, and the others were tilled and cover-cropped with crimson clover annually. The chestnut trees showed immediate improvement.

It has been demonstrated at other points on the Horticultural Farm that the Chinese chestnut succeeds best on a comparatively well-limed, fertile soil with a pH of not less than 6. The Chinese chestnut grows very slowly and cannot be expected to succeed very well, especially while young, on untilled soil in New Jersey. It has often been more seriously affected by drought than the peach or apple. For best results, the trees should receive much the same culture as a young apple orchard in this State.

The tree form is more desirable than the bush. At the time the first lot of Chinese chestnuts was planted, it was recommended that the trees be grown in bush form and allowed to form several trunks from near the ground. Most of the trees were started in that manner, but a few had single straight trunks. These bush and single-trunk tree forms are illustrated in figures 6 and 7.

After the trees were 5 or 6 years old some began to show blight infection in the narrow main crotches near the ground. None of the trees with single straight trunks developed any blight. When it seemed apparent that the formation of sharp crotches near the ground made the trees susceptible to blight, the low branches were pruned off. In some cases, the branches had become so large that the wounds were several inches across. Figure 8 shows the trunk of a Chinese chestnut which formerly had a large branch near the soil and blighted in the crotch. In contrast, figure 9 illustrates the trunk of a tree upon which no low side branches were allowed to develop.

[3] All these Chinese and Japanese chestnut trees were supplied by the U. S. Department of Agriculture.

Fig. 6. Young Chinese chestnut tree which has been allowed to develop into a bush form with low crotches near the ground.

In general, the blight cankers did not extend or renew themselves to any serious degree. The blight did continue to develop on the lower parts of the trunks of other trees in the test orchard, however, and although none of the trees died, the bark of the trunk became very rough and deeply seamed from the effect of the injury by the blight. Such trees were removed from time to time, and only those seedlings are now retained whose trunks have been relatively or entirely free from blight.

The more frequent occurrence of blight on the trunks of trees that were allowed to develop with low branches and narrow crotches may be in part associated with winter injury to such tissues (3). The bark in the crotches of limbs, and particularly of low branches near the ground, is usually more susceptible to winter injury than bark which occurs on the trunk where no limbs or branches are present. Whenever bark of the chestnut is injured or killed by some cause such as low winter temperature, an entrance for the blight organism is provided. Thus, preventing main branches from growing on the trunk near the ground and training the young tree in an upright form greatly lessens the danger of blight cankers developing on the trunk.

Fig. 7. Chinese chestnut tree which is making an upright, central leader type of growth.

Variability in tree form. A number of distinct tree forms developed among the 150 Chinese chestnut seedlings planted in 1926. The majority of the trees varied from medium-spreading to rather wide-spreading with open centers, a form similar to that of a peach tree. As illustrated in figure 10, leader shoots tended to grow at an angle, rather than directly upward. One of the trees of this spreading type measured in the summer of 1944 had a height of only 18 feet and a spread of 35 feet.

Fig. 8 (left). Trunk of Chinese chestnut tree showing large blight canker which developed in the crotch of a low branch. The branch was removed but the canker has never healed over.

Fig. 9 (right). Trunk of Chinese chestnut tree kept free of low branches and upon which no blight cankers have developed.

A few of the trees developed true central leaders and have formed a distinctly upright type, as shown in figure 7. One of these had attained a height of 34 feet and a spread of 32 feet by June, 1944.

Another variation which has appeared in the seedlings of the Chinese chestnut is the peculiar arrangement of the lateral branches on the main stem of some of the seedlings. As such seedlings develop, the lateral branches tend to arise in one plane on opposite sides of the stem, giving the young tree a fan-like appearance, as shown in figure 11.

Variability in productiveness and growth status. After several crops had been produced, marked differences were noted in the regularity of bearing and in the productiveness of individual trees throughout the collection. The variations were at least as great as among an equal number of apple seedlings.

Fig. 10. Chinese chestnut tree showing low growing, spreading habit with thick, sturdy lateral branches.

Many of the trees produced staminate flowers annually as soon as they had attained a height and spread of about 6 feet, but the majority did not form pistillate flowers so soon. Since the trees have come into bearing, a few produce annually, many biennially, and still others are uncertain as to regularity of bearing and quantity of nuts produced. It thus appears that an orchard of unselected Chinese chestnut seedlings may be very variable in production and consequently may be disappointing to the grower.

Despite the marked variation observed between individual trees, a few possessed similarity in growth status. These were of a vigorous, vegetative type which developed distinctly darker green and thicker leaves. The annual growth at the tips of branches tended to be relatively greater in diameter, and more pistillate flowers formed annually. Thus the trees tended to be annual in bearing.

Variability in size and quality of nuts. Nearly all the Chinese chestnut seedlings tested at New Brunswick produce nuts that average larger than the

Fig. 11. Seedling tree of Chinese chestnut with the branches arising in one plane, giving a fan-like appearance.

American chestnut, and some trees produce nuts that are about double the size of specimens of the common American chestnut formerly gathered in woodlands (see figure 4 and table 2). As is to be expected, the size varies somewhat from year to year because of growing conditions and the influence of pollination. The very dry weather in the summer of 1944, for example, resulted in somewhat smaller nuts than usual.

The nuts from the different seedling trees in the College Farm plantation vary also in quality. Some are of good quality, being almost as sweet and palatable as the ordinary native American chestnut and having thin skins that are readily removed from the kernels. The nuts of other seedlings are more starchy and coarse in texture and have thick pellicles or skins that do not separate readily from the kernels. Such a natural variation in productiveness and quality is to be expected in seedling trees of any species or variety.

Variations in hardiness. There is evidence of considerable variation in the relative winter-hardiness of different seedlings of the Chinese chestnut. Probably the species is no different from the apple or the peach in that respect.

Some selections being grown at New Brunswick have been hardy here but not entirely so a little farther north in the State. Smith[4] reports that the variety Hobson does not do well north of Trenton.

Varietal Selection and Development

The improvement of the Chinese chestnut may be said to be in the initial stage in America. Only a few selections as varieties are yet available. This is undoubtedly the principal reason why large numbers of seedling trees are offered for sale. No single fruit or nut crop has made much commercial progress in America except through the selection and propagation of varieties. Four varieties of Chinese chestnuts—Carr, Hobson, Zimmerman, and Yankee—have been more or less generally propagated, but they are not outstandingly desirable for any considerable range. Under such circumstances, new and better seedlings will continually appear at intervals as in apples, peaches, and other tree fruits. In order to grow only those which are the best, the chestnut grower will undoubtedly need to plan to make new plantings and change his varieties rather often until varietal improvement has advanced considerably further.

The Chinese chestnut seems to be as sensitive to length of season and temperature as such fruits as the apple and the peach. It will apparently be necessary, therefore, to select varieties for the different climatic districts, since size and quality of nuts are likely to be affected, as well as vigor and hardiness.

Propagation

Greater uniformity of tree and fruit characters among horticultural plants is attained by the propagation of a selected type by budding and grafting. This is apparently sound procedure with the chestnut and has been practiced in China for many years. The use of proper rootstocks and of suitable methods of grafting undoubtedly must be adopted. That chestnuts, like apple tree varieties, show their preferences for different rootstocks is evident from the behavior of the variety Carr.

The Growing of Rootstocks

The first essential in the propagation of a selected seedling or a named variety is the rootstock upon which to graft it. So far as is known, the Chinese chestnut is the best rootstock upon which to propagate selections of this species. Young seedlings grown from the nuts of the Chinese chestnuts will provide such plant material.

It has been the experience at New Brunswick that a considerable proportion of the nuts may rot if planted outdoors immediately after being gathered in the fall. On the other hand, good results have been obtained by placing

[4] Smith, J. R., Correspondence, 1945.

the mature nuts in damp sand in a suitable container and storing them from October to April in a cool cellar ranging from 40 to 48°. The sand must be kept moist and the nuts protected from rodents. With the advent of warm weather in early spring when the nuts are ready to sprout, they may be removed from the sand and planted directly in nursery rows or seedbeds. In some localities and seasons, the germinating nuts and young seedlings are likely to be destroyed by squirrels and other rodents unless protected in some manner.

Another procedure which has been successful at New Brunswick is to place the containers with the nuts outdoors in shade in early spring to germinate. After the first two leaves are well developed, the seedlings are transplanted into the nursery row. This method is useful where only a few nuts are to be germinated and it is desired to start them early to obtain maximum growth the first season. The weakness of this method is that the chestnut is not too easily transplanted and some skill is required for good results.

Grafting the Chestnut

Experience has shown that the Chinese chestnut cannot be grafted so readily as the apple. The tree is one of the earliest to start growth in the spring, and the grafts and scions are especially susceptible to drying out. Various methods of dormant-season grafting have been suggested, including the ordinary splice, the cleft, and the bark or inlay graft. These have all been tested at New Brunswick. Veneer or patch budding has been mentioned by some authorities but may be somewhat difficult for the inexperienced.

The ordinary splice graft has been found most successful for chestnuts by many propagators and is the method used by Dr. J. Russell Smith in his extensive nursery practice in propagating the Chinese chestnut. For success in this method the stock and the scion must be of about the same size. Two-year-old seedling stock is suitable, and well matured scion wood should be used. A smooth diagonal cut is made through the stock, and a similar cut made through the scion. The scion is then placed on the stock so that the two cut surfaces come together and the inner bark and cambium are in close contact. The graft is then wrapped tightly with raffia and covered with wax.

Dr. W. T. Chang, of the University of Nanking, China, describes a method of grafting called the "Chi-Tsi" which is said to be the most successful in China with nursery trees that are about ½ to 1 inch in diameter. The stock to be grafted is cut off as low as possible, usually about 2 inches above the ground. Then a slit about 1¼ inches long is made down one side of the stub so as to separate a thin segment of bark and wood from the remainder of the stock, as illustrated in figure 12*A*. This slit allows insertion of the scion, a short length of 1-year-old wood growth with three or four buds.

The scion is prepared much as though it were to be used for an ordinary inlay or bark graft (fig. 12*B*). It is inserted in the stock (fig. 12*C*), and the

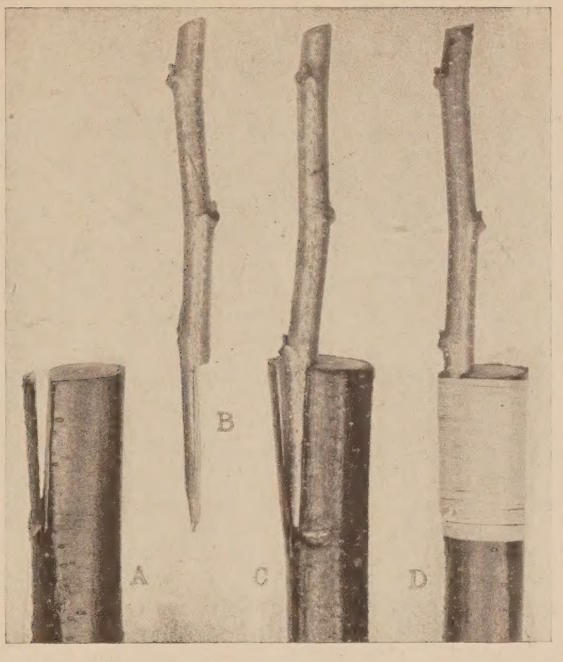

Fig. 12. A modification of the cleft graft as used in propagating the chestnut in China: A, stock showing the narrow slit near one side; B, scion; C, scion inserted in the stock; D, the completed graft tied with raffia.

graft is tied tightly with raffia (fig. 12*D*) and waxed. The soil is then mounded up around the graft just enough to cover the scion, leaving the top bud exposed, and is maintained in this manner until the graft has united.

In China, this graft is sometimes used for topworking above the surface of the ground. In such cases, it is covered with moist moss which is held in place by a sheath of bamboo leaves. Strips of cloth, tape, or other suitable material could be used for this purpose.

Suggestions for Planting

Experience in New Jersey indicates that the Chinese chestnut should be planted only where a fairly fertile, well-drained soil is available and where some cultural care such as that recommended for apple trees can be provided.

Trees from 2 to 3 years old with a height of 2 to 3 feet are a good size to transplant into a permanent location. In general, a planting distance of not less than 25 feet by 25 feet is desirable on a fertile, deep loam soil.

Pest Control

The only insect enemy of the chestnut which has done much damage at New Brunswick is the Japanese beetle. The Chinese chestnut is seriously attacked by this insect. The beetles appear to be attracted first by the catkins in late June, but they soon go to the leaves and feed on them freely unless the trees are sprayed with arsenate of lead. An effective spray may be prepared by mixing 2 pounds of arsenate of lead and 2 pounds of wheat flour with 50 gallons of water.

The chestnut weevil sometimes causes wormy nuts, but this pest has not given any trouble at New Brunswick.

Present Work with Chestnuts

Observations are being continued at New Brunswick on the growth and behavior of the most promising Chinese chestnut seedlings, the first of which was planted in 1926. In addition, seedlings are being grown from Boone, and others selected from the most promising Chinese material.

Extensive work with chestnuts is being carried on by the U. S. Department of Agriculture and elsewhere in the country. Since many thousands of chestnut seedlings of the Chinese and Japanese species are being planted (5), comparatively rapid improvement in varieties is likely.

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